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Conservation status of the first known population of *Polygala balansae* in Europe

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We studied the natural history as well as the conservation status of the first-known population of *Polygala balansae* in Europe (Granada, SE Spain). In the study area, we located only one population occupying a small patch of 1920 m^2, between 120 and 160 m a.s.l., with 246 mature individuals. The species is classified as Critically Endangered (CR), under the following criteria: severely fragmented, inferred continuous decline, small population size, and continuing decline inferred from the number mature individuals. The main threats over the population are: spreading subtropical tree-crops and encroachment of human settlements for tourist purposes, plus natural causes (drought, wild or human-mediated fire, limited dispersal, poor recruitment/reproduction/regeneration, high juvenile mortality, low densities and restricted range). Finally, passive and active conservation measures are proposed in order to guarantee the survival of the species.

Key words: conservation, habitat depletion, *Polygala balansae*, threatened plants

Introduction

The Polygalaceae are almost cosmopolitan, consisting of 22 genera with about 1000 species classified in four tribes (Polygalae, Moutabeae, Carpolobieae and Xanthophylleae; Eriksen & Persson 2007). The largest genus is *Polygala* with ca. 325 species (Heywood *et al*. 2007), of which 33 occur in Europe.

Polygala subgen. *Chamaebuxus* is thought to have only two species in Europe: *P. chamaebuxus* and *P. vayredae* (Valentine & Webb 1968), the latter being endemic to NE Spain (Alta Garrotxa, Catalonia, Spain), and it has been evaluated as vulnerable (Anon. 2000). The subgenus has three species in northern Africa (Morocco and Algeria): *P. balansae*, *P. webbiana*, and *P. mumbyana* (Ball 1877, Valdés *et al*. 2002), all of them endemic. *Polygala balansae* is distributed throughout the High Atlas, western Anti-Atlas, and some parts of the Middle Atlas (Fig. 1), where the taxa have scattered but numerous populations and consequently the species is not under extinction risk (Fennane & Tattou 1998). In this paper, we study different aspects of the natural history as well as the conservation status of the only known population of *Polygala balansae* in Europe (Granada, SE Spain).

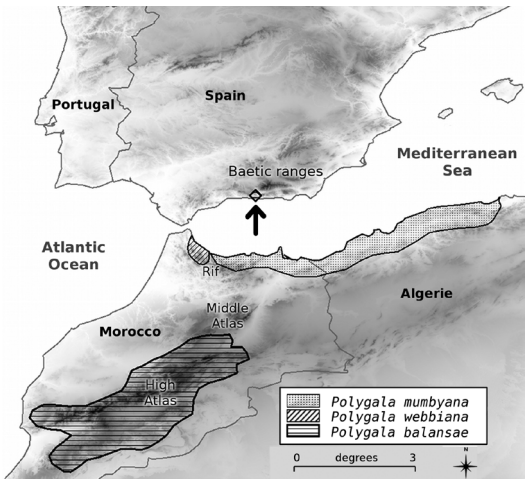

Fig. 1. Distribution of *Polygala balansae, P. webbiana* and *P. mumbyana* (modified form Charco 2001). The studied population of *P. balansae* is indicated with an arrow.

Material and methods

Polygala balansae (Fig. 2), according to Salinas and Lorite (2009), is a nanophanerophyte that reaches 1.5 m high. The glabrous branches have little striation, with the nodes and young stems somewhat pubescent, and with spiny apices. The leaves are 6–13 × 1.4–2.2 mm, deciduous, alternate, linear-lanceolate, entire, slightly pubescent, with a petiole of ca. 0.7 mm. The flowers are irregular and hermaphroditic, arranged in axillary racemes, with 3–4 flowers of which 1–3 often become aborted. Sepals number 5, and they are free and purple; two inner of them (wings) are larger and petaloid, 11.7–13.3 × 5–7 mm, deciduous, obovate or oblanceolate. Petals number 3, they are 14–18 mm long, connate and forming a purple tube with yellow lobes, the lower (keel) being entire. Stamens number 8(9), and they are monadelphous. Ovary is superior. Capsule measures 7.1–8 × 7.6–8.3 mm, is compressed, rather obovate or orbicular, has two valves and a marginal wing, and it lacks a gynophore.

The study area is located close to the town of Almuñécar (Granada province, SE Spain; Fig. 1) at ca. 130 m a.s.l. (36°44´N, 3°41´W), where the bedrock consists of schists and quartzites (García-Dueñas & Avidad 1981) and the soil type is regosol (Aguilar *et al*. 1986). The climate is dry, with an annual average precipitation of

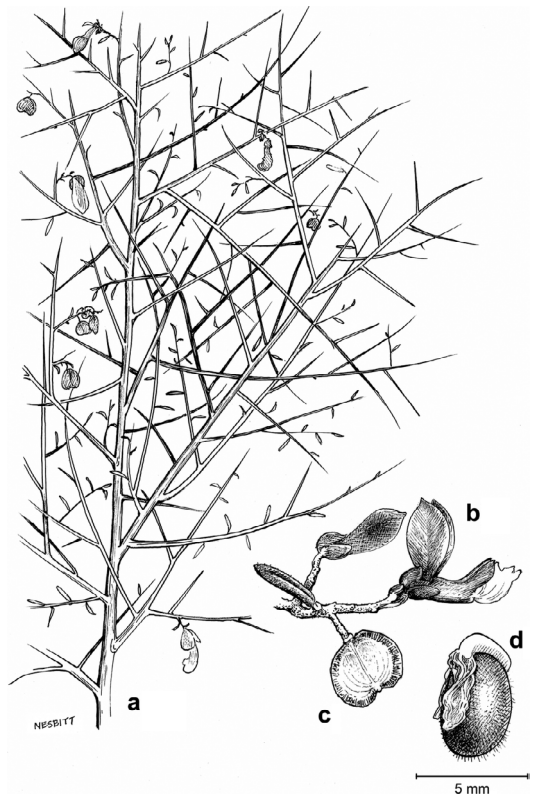

Fig. 2. Details of *Polygala balansae* (*GDA 54291*). — **a**: Habit. — **b**: Flower. — **c**: Fruit. — **d**: Seed.

475 mm (according to Valle *et al*. 2004). The average annual temperature is 17.4 °C, the hottest and coldest months being August (24.3 °C) and January (12.1 °C), respectively, and the area is free of winter frosts.

After being informed of the population of *P. balansae* (R. Salas pers. comm.), individuals of the species were located with GPS (±3 m error). With the resulting cloud of points (each point being an individual), the occupation area of the patch was calculated. The small patch size, and the easy detectability of the individuals in the flowering season allowed us to estimate the number of individuals by direct counting. In order to determine the occupation area of the species in the neighbouring zones, first potential occupation zones were selected by combining the ecological data observed for the population (geological, edaphic, climatic, vegetation type, etc.), with the help of digital orthoimages from the year 2001, with 1-m spatial resolution (source: REDIAM; Red de Información Ambi-

ental de Andalucía). Afterwards, a concentric sampling was made, beginning in the centre of the known populations and extending the sampling to the potential neighbouring zones.

To establish the age structure of the population, 90 individuals were randomly selected and their heights and plant diameters were measured. The plant volume was calculated using an equation for the volume of a semi-spheroid [$V = (4/3\pi r^2 h)/2$], where r is the plant radius and h is the plant height. Plants with greater volumes were considered older. Also, five transects of 25 × 1 m each were established in order to find seedlings or early-juvenile individuals. To determine the phenology of the population, 50 plants were randomly selected, and the phenological state of each plant was recorded. The plants were monitored eight times from the appearance of the first buds to the post-dispersal phase. To calculate fruiting success, we marked five stems per plant in five individuals, in which we counted the number of flowers (at flowering peak) and, towards the end of the fruiting phase (before seed dispersal), we counted the fruit production per each marked stem. We collected also 10 fruits per plant from 9 plants (90 fruits) to estimate the average seed production per fruit. These fruits and seeds were used to measure certain morphological aspects (*see* Results). Statistical data analysis was performed using JMP 6.0 (SAS Institute). The data are presented as ±1 SE.

Recorded qualitative data together with the data retrived from literature, enabled deductions concerning real or potential threats. Definition of these threats follow the recommendations of the IUCN/SSC (2001), and for the assignment of the endangered status, the categories of the IUCN (2001) were used with the help of the software RAMAS-Red list ver. 2.0 (Akçakaya & Ferson 2001).

Results

Population and species attributes

The population is located in Almuñecar (Granada, SE Spain) occupying an area of 1920 m^2, between 120 and 160 m a.s.l., and has 246 reproductive individuals. Further searches in potential habitats in the neighbouring areas revealed no more plants. The habitat is a Mediterranean thicket of *Maytenus senegalensis*, together with other typical mediterranean-xerophytic taxa, such as *Chamaerops humilis*, *Rhamnus lycioides*, *Olea europaea* var. *sylvestris*, *Genista umbellata*, and *Pistacia lentiscus*. The habitat is included in the Habitat Directive as a priority (Code 5220-Arborescent matorral with *Zyziphus)*.

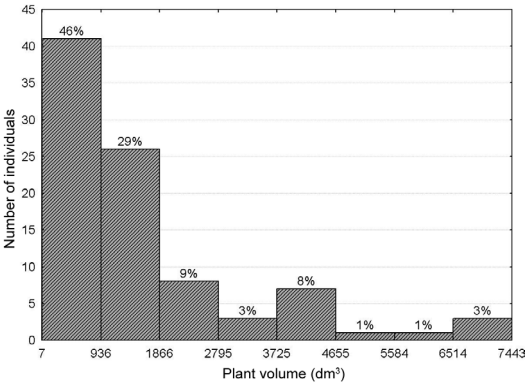

Fig. 3. Percentage and number of individuals of *Polygala balansae* in each biovolume class established (n = 90).

The age structure of the population (based on the bio-volume classes) was skewed towards the small classes (Fig. 3). A search for seedlings and young individuals revealed that there were no plants in that life-cycle stage.

The species flowers between February and April, fruits ripen mostly in April, and seeds are dispersed in May and the first two weeks of June. Fruits usually remain on the plant until mid-July. Finally, from the mid-July to the end of January all the plants are in vegetative repose (Fig. 4). In the marked stems, 25.5% ± 3.8% (n = 25) flowers produced fruits, with an estimated fruit production per plant of 430.6 ± 195.0 (n = 25; range = 2–2025 seeds per plant), with 1.00 ± 0.04 seeds per fruit (n = 99). The seeds (Fig. 2) are 5.41 ± 0.06 mm long and 2.98 ± 0.04 mm wide (n = 60), and have a white exostome arile with two wings of 3.89 ± 0.07 mm (n = 60), acting as an elaiosome (Verkerke 1985).

Threat assessment

According to IUCN (2001) categories, the species has been classified as Critically Endangered (CR).

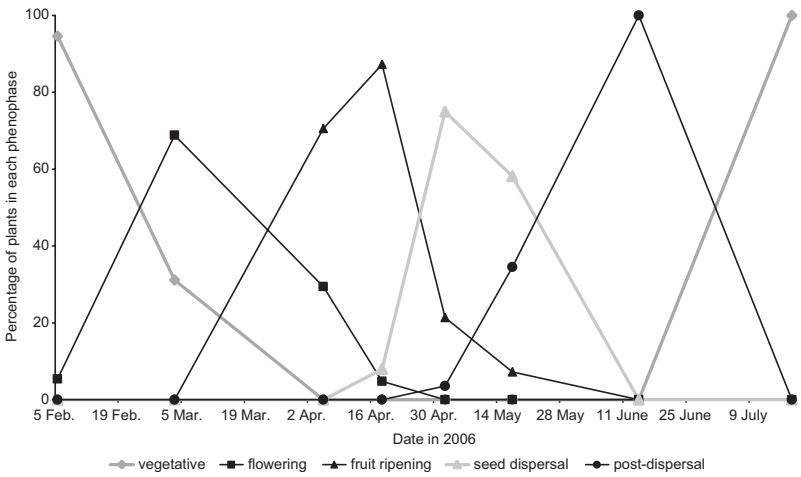

Fig. 4. Phenophases in the life cycle of *Polygala balansae*.

The main threats detected for the species were on one hand habitat fragmentation, changes in land use (e.g. spread of subtropical tree crops), and the encroachment of human settlements. On the other hand, natural threats include droughts, wild or human-mediated fires, limited dispersal, poor recruitment/reproduction/regeneration, high juvenile mortality, low densities and restricted range.

Discussion

Polygala balansae, formerly thought to be endemic to northern Africa (Morocco; Fennane & Tattou 1998, Charco 2001), has one population in the southern Spain that constitutes the first record for the species in Europe. The identification of the species is certain, since the morphological characters match the characters indicated by Ball (1877) for the North African populations. The presence of the species, together with others such as *Maytenus senegalensis*, highlights the relationship between the flora of northern Africa and southern Spain, pointed out by some authors (e.g. Mota *et al*. 2002, Lorite *et al*. 2007). The origin of the south Spain population of *P. balansae* may be traced back to the end of the Miocene, when xerophilous taxa from Africa (e.g. *Periploca*, *Zygophyllum*, *Tribulus*, etc.) arrived to the northern side of the Mediterranean basin (Quézel 1985).

The population here studied, despite the low number of reproductive individuals, flowers and fruits regularly, but no seedlings were found. Also, the age-structure of the population seems to be balanced (*see* Results). This could be due to the pulse-recruitment, typical of Mediterranean ecosystems, in which environmental stochasticity plays a major role (Alados *et al*. 2004).

The functional elaiosome attracts ants as dispersal vectors (Weekley & Brothers 2006), so the seed dispersal is mainly short-distance (Peters *et al*. 2003). On the other hand, the potential occupation area of the species has undergone a high level of degradation and is strongly fragmented, so that it is likely that this relict population is the remainder of a larger ancestral one. Despite the fact that the population seems not to be under a severe extinction risk and the seed production is relatively high, due to the poor dispersal ability and the scarcity of suitable habitats, recolonization of neighbouring areas after local extinction is quite unlikely. This fact indicates the negative effects of habitat fragmentation, pointed out by other authors (Mota *et al*. 1996, Benito *et al*. 2009).

The evaluation of the species as Critically Endangered, due to human-mediated factors such as the spread of subtropical tree-crops (ca. 100 m away) and tourist settlements (ca. 300 m away), together with the population features, is another example of depletion of fragile and original Mediterranean-semiarid habitat type (e.g. Mota *et al*. 1996, Anadón *et al*. 2006) included in the European Habitat Directive. The significance of the habitat for conservation purposes is supported by the presence of some threatened species at the regional and European level, such as

Maytenus senegalensis subsp. *europaeus*, *Buxus balearica,* and *Cneorum tricoccum* (Blanca *et al*. 1999, 2000, Cabezudo *et al*. 2005).

As conservation measures we propose the inclusion of the species in the national and regional red lists, currently under revision. As more active conservation measures we propose the protection of the population in the habitat patch here studied, as well as the reintroduction and benign introduction (*sensu* IUCN 1998) in suitable neighbouring areas, where remains of suitable vegetation and habitat exist.

The results of our study emphasize a need for urgent conservation measures to protect the few remaining sites where this vegetation type (i.e. arborescent semiarid *matorral*) can thrive, these being restricted to the southeastern Spain (Murcia, Almería, Granada and Málaga provinces), and with no protection guaranteed by the current network of natural protected areas.

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